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Emergency tillage to control wind erosion: Influences on winter wheat yields

Leon Lyles and John Tatarko

*ABSTRACT: About 2.4 million hectares (6 million acres) are tilled on an emergency basis each year to control wind erosion in the Great Plains. Much of the tillage is done on fall-seeded winter wheat (*Triticum aestivum *L.). Emergency chiseling of growing winter wheat in Finney County, Kansas, during early March (1977-1981) did not significantly influence grain yields on a silty clay site, regardless of whether a 76- or 152-centimeter (30- or 60-inch) chisel spacing was used, whether 50 or 100 percent of the area was tilled, or whether tillage was parallel or perpendicular to row direction. Similar results were obtained in 3 of 4 years on a sandy loam site. Narrow-point chisels have potential for reducing wind erosion if soil conditions are conducive to producing nonerodible aggregates. Wheat straw/grain ratios, stalk diameters, and volume weights are important factors in determining what wind erosion protection the vegetation is able to provide.*

WHEN vegetative cover is sparse or absent on cropland, other wind erosion control methods become necessary. The most common method of last resort is emergency tillage. This practice is used every year in the Great Plains, much of it on fall-seeded winter wheat (*Triticum aestivum* L.).

Over the last 14 years (1968-1981), according to Soil Conservation Service reports, farmers in the 10 Great Plains states emergency tilled an average of 2.4 million hectares (6 million acres) annually to control wind erosion. Such tillage creates a cloddy surface of nonerodible aggregates and furrows to trap eroding particles or aggregates. The most common implements used for emergency tillage are narrow-point chisels on medium- and fine-textured soils and listers on coarser textured soils.

Leon Lyles is research leader with the Agricultural Research Service, U.S. Department of Agriculture, Manhattan, Kansas 66506, and John Tatarko is a research assistant in the Agronomy Department, Kansas State University, Manhattan. Contribution from the U.S. Department of Agriculture, Agricultural Research Service, in cooperation with the Kansas Agricultural Experiment Station. Department of Agronomy Contribution 82-340-J.

Limited information exists to help growers decide what tillage intensity to use and still expect to harvest a crop. In a nonreplicated study at the Southwest Kansas Experimental Field near Minneola, Kansas, emergency chiseling on 102-centimeter (40-inch) centers reduced wheat yields an average of 67 kilograms per hectare (1 bushel/acre) over a 13-year period (unpublished data). The average yield reduction on the chiseled area in the first 5 years, however, was 370 kilograms per hectare (5.5 bushels/acre).

Our field study sought to determine how tillage tool spacing, percentage of area tilled, tillage direction relative to row direction, and soil type influenced winter wheat yields.

Experimental procedure

We conducted our field experiment on two sites: a Manter fine sandy loam (site 1) (Typic Haplustoll; coarse-loamy, mixed, mesic) and a Spearville silty clay (site 2) (Typic Argiustoll; fine, montmorillonitic, mesic) in Finney County, Kansas. The statistical design, a split-plot randomized block with three replicates, included main plots with two tillage directions, one parallel to row direction, the other perpendicular. Subplots [96 square meters (1,024 square feet)] included all combinations of 76-centimeter (30-inch) and 152-centimeter (60-inch) chisel spacing and 50 and 100 percent of area tilled. Each main plot included a control plot without tillage.

The fall-seeded winter wheat was emergency tilled between March 8 and 14 each year with 5.1-centimeter (2-inch), narrow-point chisels operating 10 to 13 centimeters (4-5 inches) deep; ground speed was about 1.8 meters per second (4 miles per hour).

We collected soil aggregates from the surface 2.5 centimeters (1 inch) with a flat spade before and after tillage from each of the six main plots annually. Those collected after tillage were from the chisel paths. After air drying, the aggregates were rotary sieved to determine nonerodible aggregates greater than 0.84 millimeters in diameter. A second sieving determined the mechanical stability of the aggregates.

Beginning in 1978, we determined soil water gravimetrically to 1.22 meters (4 feet) at tillage and harvest each year in three of the control subplots. Rainfall between tillage and harvest was measured with nonrecording gages located at site 1 and about 5 kilometers (3 miles) northeast of site 2.

Except for 1979, we determined wheat yields from two hand-harvested transects, 0.6 by 9.1 meters (2 x 30 feet), in each subplot. The entire subplot area was combined in 1979.

All seeding, land preparation, wheat variety choice (Eagle at site 1, Larned at site 2), and decisions on fertilizer were made by the land operators, who were using a wheat-fallow rotation. Each year, wheat yields were possible in the wheat-fallow rotation by moving the plot area about 18 meters (60 feet) north or south. No fertilizer was applied at site 2 in any year or at site 1 in 1978. However, 44.8 kilograms of nitrogen per hectare (40 pounds/acre) was applied at site 1 each year (1979-1981) thereafter. Both operators used a 30.5-centimeter (12-inch) row spacing and seeding rates of 40 to 50 kilograms per hectare (35 to 45 pounds/acre).

Results and discussion

Soil aggregates. Nonerodible surface aggregates before tillage ranged from 11 to 40 percent at the sandy loam site and from 27 to 80 percent at the silty clay site (Table 1). Corresponding values after chiseling were 32 to 62 percent and 78 to 95 percent,

Table 1. Effect of chiseling on size and mechanical stability of soil aggregates at two sites in Finney County, Kansas, 1977-1981.

Location and Treatment	1977	1978	1979	1980	1981	Average
Site 1			Aggregates>0.84 mm, %			
Before	10.9	16.2	14.0	33.9	13.6	17.7
After	32.0	49.2	50.9	62.0	43.4	47.5
Change	+21.1	+33.0	+36.9	+28.1	+29.8	+29.8
			Mechanical stability, %			
Before	47.7	35.3	26.3	47.7	42.4	39.9
After	62.1	61.6	67.0	70.7	55.7	63.4
Change	+14.4	+26.3	+40.7	+23.0	+13.3	+23.5
Site 2			Aggregates>0.84 mm, %			
Before	65.1	79.9	26.7	44.5	53.1	53.9
After	77.6	95.0*	77.8	80.2	87.8	83.7
Change	+12.5	+15.1	+51.1	+35.7	+34.7	+29.8
			Mechanical stability, %			
Before	87.8	81.6	51.5	66.7	74.6	72.4
After	94.4	95.0*	90.7	92.0	93.5	93.1
Change	+6.6	+13.4	+39.2	+25.3	+18.9	+20.7

*Estimated.

Table 2. Effect of emergency tillage variables on winter wheat yield on a silty clay soil (site 2) in Finney County, Kansas.

Variable	1977	1978	1979	1980	1981	Average
			Kg/ha			
Tillage parallel to row	1,250*	-†	1,940*	1,550*	-†	1,580
Tillage perpendicular to row	1,160	-	1,930	1,560	-	1,550
50% areal coverage	1,210	-	1,880	1,610	-	1,570
100% areal coverage	1,200	-	1,990	1,690	-	1,630
76-cm (30-in) chisel spacing	1,180	-	1,860	1,630	-	1,560
152-cm (60-in) chisel spacing	1,220	-	2,020	1,680	-	1,640
Control	1,180	-	1,980	1,580	-	1,580
Average	1,200	-	1,940	1,610	-	1,590

*Means in a column are not significantly different at the 95 percent level.
†Hailed out.

Table 3. Effect of emergency tillage variables on winter wheat yield on a sandy loam soil (site 1) in Finney County, Kansas.

Variable	1977	1978	1979	1980	1981	Average
			Kg/ha			
Tillage parallel to row	-*	780a†	1,560a	1,130b	2,100a	1,390
Tillage perpendicular to row	-	850a	1,750a	1,260b	2,140a	1,500
50 percent areal coverage	-	860a	1,630a	1,490b	2,230a	1,550
100 percent areal coverage	-	770a	1,680a	900c	2,000a	1,340
76-cm (30-in) chisel spacing	-	810a	1,600a	900c	2,070a	1,350
152-cm (60-in) chisel spacing	-	820a	1,710a	1,490b	2,170a	1,550
Control	-	870a	1,810a	2,050a	2,040a	1,690
Average	-	820	1,680	1,320	2,110	1,480

*Hailed out.
†Means followed by same letter are not significantly different at the 95 percent level.

Table 4. Water use and water-use efficiency for winter wheat on control plots at two sites in Finney County, Kansas.

Year	Rainfall (cm)* Site 1	Rainfall (cm)* Site 2	Water Use (cm)† Site 1	Water Use (cm)† Site 2	Yield/Water (kg/ha•cm) Site 1	Yield/Water (kg/ha•cm) Site 2
1978	33.88	-	33.91	-	26	-
1979	23.75	26.82	41.68	38.00	43	52
1980	26.19	31.22	38.35	33.40	54	47
1981	19.63	-	31.06	-	66	-
Average	25.86	29.02	36.25	35.70	47	50

*March 10-June 30.
†Rainfall plus change in soil water storage between tillage and harvest in top 1.22 m (4 ft).

respectively. The average change due to chiseling was about + 30 percentage points for each site, although the numerical values were quite different. Based on wind-erodibility factors, I (*11*), chiseling the sandy loam could reduce that factor from 238 to 99 metric tons per hectare•year (107 to 44 tons/acre•year); in the case of the silty clay the reduction could be from 65 to 0 metric tons per hectare•year (31 to 0 tons/acre•year). (I factors represent estimated annual erosion amounts from smooth, bare, wide fields located near Garden City, Kansas.) With these values, we assumed that chisel-generated aggregates cover the entire surface area, which is unlikely for the wider chisel spacing and for areal coverage less than 100 percent. The data do show, however, the potential for emergency tillage to reduce wind erosion if soil conditions are conducive to producing nonerodible aggregates.

Two facts were obvious from the mechanical stability data (Table 1). First, the fine-textured soil contained more stable aggregates than did the coarse-textured soil. Second, freshly chiseled soil contained more stable aggregates than did untilled surface soil, regardless of texture.

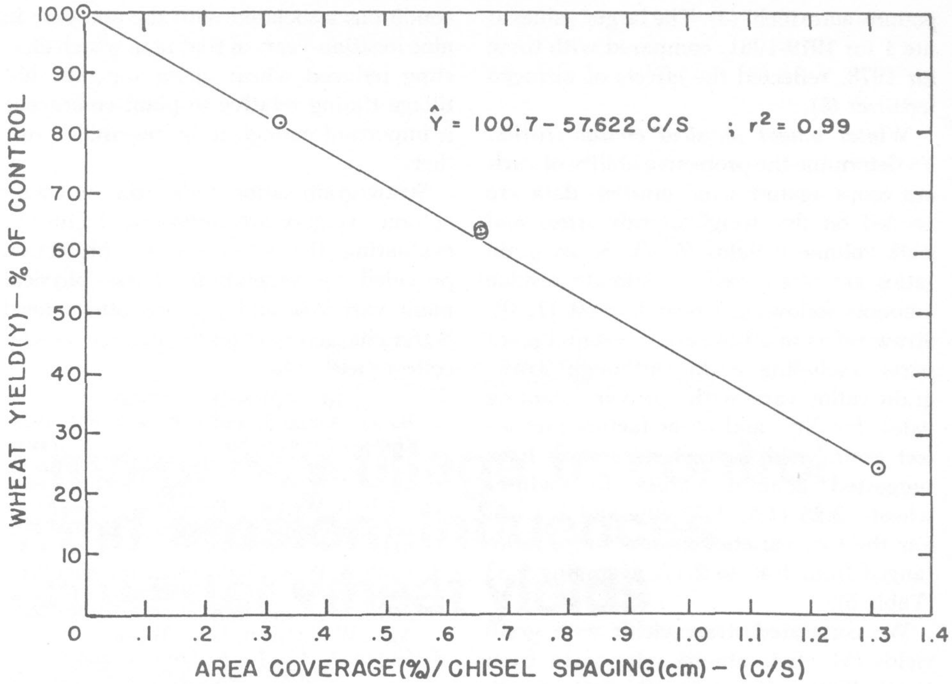

Figure 1. Wheat yield as related to the ratio of tilled area (coverage, %) to chisel spacing (centimeters), site 1, 1980, Finney County, Kansas.

Wheat yields. We were surprised at wheat yields following the chiseling, especially the first year. During tillage, considerable wheat appeared (visually) to be plowed out or covered with soil, especially with the closer chisel spacing and 100 percent areal coverage. We anticipated a yield reduction. But none of the treatment variables influenced yields any year at the silty clay site (Table 2). Because of hail, no yield data were available in 1978 or 1981. No visual differences in plant growth and population, however, were evident during those years.

At the sandy loam site (Table 3), none of the treatments influenced wheat yields, except in 1980. During that crop year, no rain occurred for 35 days following wheat seeding on September 25, 1979, and no plants emerged until the second week in November. Cold temperatures during the last week in November and in December permitted little top and root growth and encouraged dormancy. When tillage began on March 11, 1980, the wheat was hardly visible, consisting of single shoots about 2.5 centimeters (1 inch) tall. The plants did not survive in the tillage zones, and yields at harvest were reduced 27 to 56 percent.

The larger reductions, as expected, were associated with the closer chisel spacing and 100 percent areal coverage. Apparently, soil thrown up by the chisels covered and killed the small plants. Because of limited early plant development, the potential number of tillers probably was reduced, resulting in plants that were more vulnerable to damage by the tillage treatments. Also, the tillage zones were overgrown with weeds, which competed with the surviving wheat plants for water and nutrients.

These results suggest that emergency tillage fairly soon after emergence in the fall, before plants can make sufficient top and root growth, can be expected to reduce yields. Our study showed that the reductions related linearly to the ratio of area covered to chisel spacing (Figure 1). Emergency chiseling of spring wheat probably would reduce yields also. We should not obscure the principal finding that emergency chiseling did not affect wheat growth in any of 5 years at site 2, or in 4 of 5 years at site 1. Because no wind erosion occurred, our study only evaluated tillage effects on wheat yield, not the combined effects of tillage and blowing soil.

Table 5. Stalk diameters, volume weights, and straw/grain ratios for winter wheat at two sites in Finney County, Kansas, 1978-1981.

Location and Variable	*Years* 1978	1979	1980	1981	*Average*
Site 1 (wheat variety: Eagle)					
Stalk diameter (cm)*	0.24	0.29	0.26	0.27	0.26
Volume weight (g/cm³)*	0.18	0.19	0.20	0.23	0.20
Volume weight (g/cm³)†	0.30	0.30	0.28	0.34	0.30
Straw weight/grain weight	1.93	1.91	1.46	-	1.81
Site 2 (wheat variety: Larned)					
Stalk diameter (cm)*	-‡	0.27	0.26	-‡	0.26
Volume weight (g/cm³)*	-	0.16	0.18	-	0.17
Volume weight (g/cm³)†	-	0.24	0.25	-	0.24
Straw weight/grain weight	-	1.68	2.17	-	1.97

*Lower 30.5 centimeters without leaves.
†Lower 30.5 centimeters with leaves.
‡Hailed out.

Water use. Although determining water use was not a major objective of our study, soil water, rainfall, and grain yield data allowed calculations of water-use efficiency (Table 4). The results agreed with published water-use efficiencies between 16 and 42 kilograms per hectare•centimeter (36-95 pounds/acre•in) at North Platte, Nebraska, and 56 kilograms per hectare•centimeter (127 pounds/acre•inch) at Garden City, Kansas (5). Expected water-use efficiency for the shorter winter wheat cultivars in the west central Great Plains is 50 kilograms per hectare•centimeter (113 pounds/acre•inch) (*3*). The larger values at site 1 for 1979-1981, compared with those for 1978, reflected the effects of nitrogen fertilizer (*5*).

Winter wheat physical characteristics. To determine the protective ability of various crops against wind erosion, data are needed on dry weights, stalk sizes, and stalk volume weights (*6*, *7*). Straw/grain ratios are often used to estimate residue amounts following wheat harvest (*1*, *9*). Straw refers to all the above-ground plant parts, excluding grain. Although straw/grain ratios vary with cultivar, planting dates, fertility, and other factors that affect grain yield, several researchers have suggested general values for winter wheat—2.25 (*10*), 1.75 (*9*), and 1.7 (*4*). For the two varieties in our study, ratios ranged from 1.46 to 2.17, averaging 1.83 (Table 5).

We correlated straw yields with grain yields (51 observations) using data from North Platte, Nebraska (*8*), and unpublished data from Whitman County, Washington, and Sidney, Montana. The linear regression equation was $S = 1387 + 1.0725G$, $r = 0.72$, where S and G are straw and grain yields, respectively, in kilograms per hectare. Input G values were between 1,600 and 6,000 kilograms per hectare. Using average U.S. winter wheat yields for 1965-1979 of 2,109 kilograms per hectare (31.4 bushels/acre) in the equation, we calculated a straw/grain ratio of 1.73, which agrees closely with published values (*4*, *9*). Using our overall average yields (control) in the equation gave a ratio of 1.91, compared with the measured value of 1.83.

Our average values for stalk diameter (0.26 centimeter) and volume weight (without leaves) (0.19 grams/cubic centimeter) agreed closely with published values of 0.25 centimeter and 0.18 gram per cubic centimeter, respectively (*2*). About one-third of the lower 30 centimeters of stalk weight was leaves (Table 5).

Conclusions

Narrow-point chisels have potential for creating nonerodible aggregates, which reduce wind erosion, but soil conditions conducive to producing nonerodible aggregates must exist at tillage.

In six of seven cases, emergency chiseling in late winter did not affect subsequent wheat yields, regardless of chisel spacing, percentage of tilled area, tillage direction relative to row direction, or soil type. This information provides some guidelines for performing emergency tillage, allowing a wider choice of operational variables. However, the plant growth and climatic conditions associated with the one year in nine location-years of testing in which chiseling reduced wheat yields suggests that tillage timing relative to plant emergence is important enough to be researched further.

Straw/grain ratios, stalk sizes, and stalk volume weights are important factors in evaluating the wind erosion protection provided by vegetation. These physical plant variables and perhaps others need better characterization by researchers who collect yield data.

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